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SCI MODEL STRUCTURE DETERMINATION PROGRAM (OSR)
USER'S GUIDE

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I. INTRODUCTION AND OVERVIEW

System identification technology has been used successfully for many vehicles. Because of their large number of degrees of freedom and complex aerodynamic interactions, the rotorcraft have always presented a special challenge to system identification methods. A completely integrated methodology has been developed under this NASA contract to solve this difficult problem. This methodology has also been translated into a user oriented series of computer programs. This volume provides basic guidelines for efficient and effective use of one of these computer programs.

Figure 1 shows a schematic flowchart of the overall data processing technique for rotorcraft. The first step in this procedure is state estimation and instrument calibration. This is implemented by the computer program DEKFIS (for Discrete Extended Kalman Filter and Smoother which implements an extended Kalman filter/smoother using the Friedland-Duffy formulation. Instrument biases and scale factors are estimated at this stage together with any state which is not measured directly. The second step involves estimation of the mathematical model of various forces, moments and interchanges. This is implemented in OSR (Optimal Subset Regression) computer program which uses a regression technique. Accurate estimates of parameters are obtained in the final step. One of two computer programs is used for this purpose. SCIDNT implements the maximum likelihood method for linear systems and NLSCIDNT extends the method to nonlinear rotorcraft models.

The contract research effort which led to the results in this report was financially supported by the Structures Laboratory, USARTL (AVRADCOM), NASA Langley Research Center and NASA Ames Research Center.

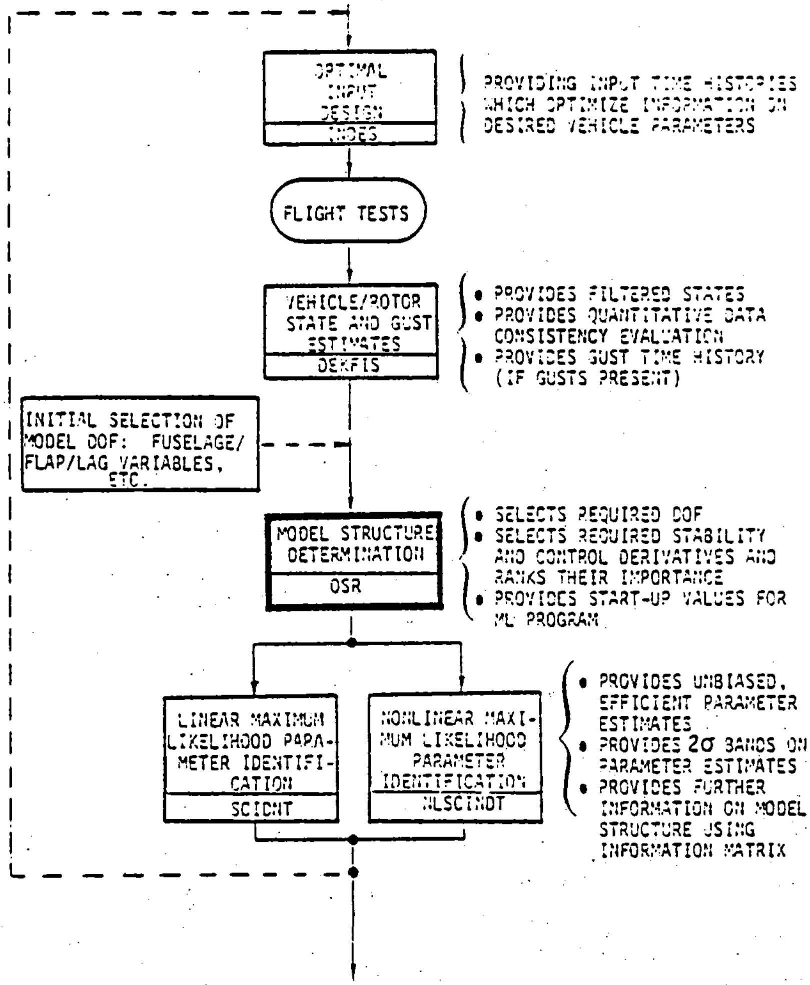

Figure 1 Integrated Rotorcraft System Identification Procedure

Accuracy of parameter estimates may be improved by using flight test inputs based on the input design program, INDES.

This user's manual describes the OSR computer program. The details of the theory and the particular implementation used are given in the final report.*

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* Hall, W.E., Gupta, N.K., Hansen, R. and Bohn, J., "State Estimation and Parameter Identification for Rotorcraft," final report on contract NAS1-14549, May 1978.

II. BACKGROUND

The computer program, OSR (Optimal Subset Regression) estimates models for rotorcraft body and rotor force and moment coefficients. The technique used is based on the subset regression algorithm, described extensively in Draper and Smith [1]. Given time histories of aerodynamic coefficients (e.g. C_x, C_y, C_z, etc.), aerodynamic variables (e.g. forward speed, angle-of-attack, etc.) and control inputs, the program computes correlation between various time histories and the model structure determination is based on these correlations. The procedure may be described as follows. Consider a single force or moment coefficient y and assume that it may be a non-linear function of several aerodyanmic variables or control inputs, x' (called independent variables). A number of functions of x' are formed to describe all possible relations between y and x'. Let x be a collection of such functions; y and x are assumed to be related by the equation:

$$y = x^T \Theta + e \tag{1}$$

where Θ is an Mx1 vector of unknown parameters and e is noise. For sake of simplicity e is assumed white and gaussian. If there are N measurements, Equation (1) may be written as:

$$Y = X\Theta + e$$

where Y is an Nx1 vector and X is an NxM matrix. The program then performs a series of hypotehsis tests based on the F-ratio criterion to determine which Θ's are zero. The x terms corresponding to non-zero Θ's are the model forms for the corresponding aerodynamic force or moment coefficient.

The program has the following features:

(1) The program is set up for rotorcraft models.

(2) The coefficients, x, are specified in a separate subroutine. Therefore, the form and number of functional forms of basic variables may be changed easily.

(3) Each force or moment coefficient is treated separately, allowing maximum flexibility.

(4) Upto 80 terms may be specified in each model.

(5) Any term may be forced in the equation. Also terms may be forced out of the equation.

(6) Time histories of measured and estimated variables (based on the model structure) may be printed out if desired.

III. PROGRAM STRUCTURE

This section gives a brief discussion of the major subroutines and functional blocks of OSR. Figure 3.1 shows the basic program structure.

The main routine, MAIN reads the data sets up the problem and does most of the computation. Most of the other subroutines are special purpose subprograms. From user viewpoint only the TRANSG subroutine is of importance.

The TRANSG routine uses an initial set of variables to create new sets of variables. For example given α we may create an α^2 time history in this subroutine. Other variables may be added as desired. In general this subroutine has to be changed for each run. However, for projects in which the model (i.e., TRANSG) remains unchanged, the appropriate TRANSG subroutine can be incorporated into OSR at the beginning of the project and remain unchanged through the end of the project.

Other parts of Figure 3.1 are self descriptive.

MAIN

Read input — RDBL2: Read and write labels for printout

↓

Create new variables — TRANSG: Compute new variables based on input data

↓

Compute covariance matrix

↓

Compute correlation matrix

↓

Enter a variable — STEPRG: Determine variable to be included — STEP: Compute parameter estimate and update correlation matrix

↓

Compute regression equation coefficients, standard error and F-ratio-to-remove for for variables in the equation

↓

Compute partial correlation coefficient, tolerance and F-ratio for variables out of the equation

↓

Print regression table — WHICHX

↓

Check if a variable should be removed from the equation

↓

Check if a new variable may be entered. If not proceed to next step

↓

Compute residuals — RESIDS: Reread mass storage device

↓

Print residuals, if desired

Figure 3.1. OSR Basic Program Structure

IV. INPUTS TO THE PROGRAM

OSR requires three classes of input. The first type, which always consists of cards, defines the structure of the time history file, specifies program tolerances and constraints, and determines types of output.

The second type of input, referred to as the time-history input or input data file, consists of tabular values of control settings, state variable, and other relevant model parameter time histories. This data can consist of cards, which would then be read with data of the first type, or a file on a mass storage device (disk or tape). No choice as to the logical unit number is permissible and it must be TAPE4. The format of the input data file is defined in the input of the first type.

The third type of input is not program data but rather a user supplied subroutine. The purpose of this routine is to enable the user to generate additional variables which are functions of the original variables read from the input data file. The structure of the subroutine, called TRANSG, is shown in Figure 4.1. The first NOV elements of array X contains the original variables read from the input data file arranged according to the sorting array (see TABLE 4.1, card type 4).

A sample input deck is shown in Figure 4.2.

Table 4.1

CARD TYPE	COLUMNS	FORMAT	NAME	DESCRIPTION
1	1-52	13A4	ITITLE	Alphanumeric title for the problem
2	1-5	I5	N	Number of data points to be used
	6-10	I5	NSKIP	Number of data points to be skipped on input data file
	11-15	I5	NOV	Number of variables from input data to be used in regression analysis
	16-20	I5	NVA	Number of variables added by transgeneration (i.e., by TRANSG) to be used in regression
	22-25	A4	ZEROI	YES if the y regression equation is to pass through the origin, NO if not. (The word YES or NO must be left justified)
	27-30	A4	STOR9	YES if the mean and covariance matrices are to be written on TAPE9, otherwise leave blank
	31-35	I5	NITEM	Number of variables read per record on input data file (NITEM $\geq$ NOV)
	36-40	I5	NTRANS	=0 TRANSG not called and no variables are added by transgeneration. $\neq$0 TRANSG is called and variables are added by transgeneration
3	Blank card required			
4	1-80	40I2	ISORT(I), I=1,NOV	Vector to specify the selection and order of variables to be used in the analysis. The Ith variable in the analysis will be the ISORT(I) element of the input data file

Table 4.1 (Continued)

CARD TYPE	COLUMNS	FORMAT	NAME	DESCRIPTION
5	1-3	I3	NAIT	Logical unit number for data input file. (May be 5 for card input or 7 for disk or tape only)
	4-6	I3	NVFC	Number of variable format cards. (This card is the first and may be the only one, ten is maximum.)
	9-80	18A4	RES(I), I=1,18	Format specification for reading input data file; if RES(1) is blank, file is assumed to be unformatted data
6	1-80	20A4	RES(I), I=19,...	
7	1	A1	ECHK	Blank if table information follows. * terminates the reading of this card type and the remainder of this card is ignored
	2-3	I2	K	Index of the variables corresponding to the first of the following tables
	5-76	9A8	DUMY	8-character tables for variables K to K+8. NOTE: only six characters are printed in most of the output
8	1-7	1-7	LBIAS	=TRUE if any of the variables are to be biased =FALSE if none are biased and no cards of type 9 are read
9	1	A1	ECHR	Blank if bias information follows. * terminates the reading of this card type and the remainder of this card

Table 4.1 (Continued)

CARD TYPE	COLUMNS	FORMAT	NAME	DESCRIPTION
	2-4	I3	L	Index of variable to be biased
	5-15	F11.0	BIAS(L)	Value of the bias NOTE: bias will be subtracted from variable before transgression variables are added
10		RES	X(I),I=1, NITEM	If time history data file consists of cards read them here
Subproblem cards; may include as many subproblem card sets as desired.				
11	1-48	12A4	ITITLE(I), I=14,25	Alphanumeric title information identifying subproblem
12	1-5	I5	KDEP	Index of the dependent variable
	6-10	I5	MAXSTP	Maximum number of iterations permitted MAXSTP$\leq$2*(NOV+NVA)
	13-15	A3	RESID	=YES if residuals are to be printed or plotted
	18-20	A3	SUMTAB	=YES if summary table is to be printed
	21-30	F10.0	FIN	F value for inclusion
	31-40	F10.0	FOU	F value for deletion
	41-50	F10.0	TO	Tolerance level
	51-60	F10.0	ERTEST	Regression steps will step when $R^2 \geq 1.0$-ERTEST
	61-65	L5	PRTRES	TRUE if table of residuals is to be printed
	66-70	L5	PLTRES	TRUE if plots of residuals are desired
13	1-80	80I1	C(I),I=1, NOV+NVA	Flag to indicate status of the variables in this subproblem.

Table 4.1 (Continued)

CARD TYPE	COLUMNS	FORMAT	NAME	DESCRIPTION
				C(I)=1; Ith variable is not to be used in any possible regression equation C(I)=2; Ith variable is an independent variable for this subproblem and may be used in regression equation C(I)=3,4,...,9; Ith variable will be forced into the regression equation. All variables with C(I)=9 will be forced in first followed by variables with C(I)=8, etc. Note: If C(I)≤ 0 the program sets it to 2. The dependent variable has its C(I) set to 1 by the program.

```
SUBROUTINE TRANSG (X, NOV, NVA)

DIMENSION X(1)

Statements defining added variables or modifications of
original variables

RETURN
END
```

Figure 4.1

```
1     RSRA2 RUN
  127     0    19     0 YES            60     0
blank card
 6252627282930313240414243131415161718
  7  1
  1 ROOT      U        V        W        P        Q        R        PHI      THETA
 10 LONG      LAT      COLL     PED      XR       YR       ZR       LR       MR
 19 NR
*
TRUE
   1 0.00454739
   2 101.398
   3 -0.0921231
   4 0.0075424
   5 0.0
   6 0.0
   7 0.0
   8 -0.0233797
   9 0.0397513
  10 57.4264
  11 46.5761
  12 29.5557
  13 66.3120
  14 1.52324
  15 -.432464
  16 -31.1885
  17 -.271331
  18 -.0561135
  19 .271085
*
PROBLEM-  ROOT AS DEPENDENT VARIABLE
   1   20  YES  YES 2.0       2.0        .001       .0001        T    T    F
12222222222222222222222222
```

Figure 4.2 Input Data

V. OUTPUTS OF THE PROGRAM

Output from the program consists of a title page with input data information (Figure 5.1), one or more pages of the first twenty time history points (Figure 5.2), one or more pages showing the mean and standard deviation of the variables (Figure 5.3), one or more pages showing the covariance matrix (Figure 5.4), one or more pages of the correlation matrix (Figure 5.5), and one or more pages of a summary for each iteration done by the program (Figure 5.6).

In addition to the standard output above, there are three optional output capabilities controlled by variables on card type 12:

1) A summary table indicating what variables were entered or removed from the regression equation during the run. (Figure 5.7).

2) A list of residuals consisting of actual and computed values for the dependent variable, the difference between the actual and computed values of the dependent variable, the relative error of the difference, and the first five variables included in the regression equation. (Figure 5.8).

3) A printer plot of actual and calculated time histories for the dependent variable (Figure 5.9).

VI. FILE DESCRIPTION

Besides the card reader and printer, the following files are used by the program:

- TAPE2 contains time histories of the original and also the transgenerated variables. It is needed to calculate the residuals of the variables being regressed.
- TAPE3 contains the summary table for the current regression run.
- TAPE4 contains the time history input data.
- TAPE9 contains the mean and covariance matrix for all variables, both original and transgenerated.

```
1     RSRA2 RUN

*************************************************************
*                                                           *
*          OPTIMAL SUBSET REGRESSION PROGRAM                *
*          ---------------------------------                *
*                                                           *
*      MODEL STRUCTURE DETERMINATION PROCEDURE              *
*        FOR USE IN PARAMETER IDENTIFICATION                *
*                                                           *
*                              DEVELOPED BY:                *
*                              SYSTEMS CONTROL, INC. (VT.)  *
*                              PALO ALTO, CAL.              *
*                                                           *
*************************************************************


NUMBER OF DATA POINTS . . . . . . . . . . 127
NUMBER OF POINTS TO SKIP OVER . . . .       0

NUMBER OF ORIGINAL VARIABLES. . . . .      19
NUMBER OF GENERATED VARIABLES . . . .       0
NUMBER OF TOTAL VARIABLES . . . . . .      19
```

Figure 5.1   Input Data Information

FIRST 20 POINTS OF INPUT DATA...

ROOT / LAT	U / COLL	V / PED	W / AR	P / FR	Q / ZR	R / LR	PHI / AR	THETA / NR	LONG
-4.445745E-03	-2.913666E-04	2.384457E-09	6.07161E-01	0.	0.	0.	-3.23233E-05	-3.77255E-08	0.
0.	0.	0.	3.19143E-06	-5.02295E-02	1.04661E-06	-2.62225E-07	-3.79233E-03	-1.04232E-07	
1.237052E-03	-3.22220E-03	1.03273E-02	-2.52599E-01	6.57717E-03	-1.20277E-03	9.55265E-05	5.25105E-05	-3.977[illegible]	1.00000E+01
0.	0.	0.	1.70155E-01	7.02770E-02	6.72357E-01	3.72551E-02	-2.45647E-02	2.0328E-03	
4.42791E-03	4.07116E-02	2.13341E-02	-2.94145E-01	1.53315E-02	-6.31294E-03	2.47235E-03	2.66254E-03	-7.23477E-04	1.00000E+01
0.	0.	0.	5.06201E-01	1.02190E-01	1.29973E+00	3.25075E-02	-3.51023E-02	5.05163E-03	
5.94175E-03	1.32910E-01	1.75767E-02	4.21591E-02	1.91702E-02	-1.56031E-02	5.33357E-03	6.21215E-03	-2.77576E-03	1.00000E+01
0.	0.	0.	4.99043E-01	1.16358E-01	1.71746E+00	1.78999E-02	-4.5[illegible]E-02	7.2[illegible]E-03	
5.35034E-03	2.75680E-01	5.74105E-03	1.72278E-01	2.10677E-02	-2.52300E-02	6.39647E-03	1.03730E-02	-6.72095E-03	1.00000E+01
0.	0.	0.	6.31015E-01	9.29111E-02	2.01123E+00	-7.56971E-03	-2.76239E-02	1.03127E-03	
4.74417E-03	4.72860E-01	-1.02575E-02	6.02391E-02	2.01566E-02	-3.73212E-02	8.36193E-03	1.56180E-02	-1.29520E-02	1.00000E+01
0.	0.	0.	7.23045E-01	1.03463E-01	2.25778E+00	-1.20467E-02	-5.64230E-02	9.71[illegible]E-03	
3.36595E-03	7.31602E-01	-5.21585E-02	-1.13293E-01	1.97731E-02	-5.02352E-02	1.03776E-02	1.67203E-02	-2.16770E-02	1.00000E+01
0.	0.	0.	7.90156E-01	1.21462E-01	2.50603E+00	-1.70662E-02	-7.29177E-02	1.03453E-02	
1.98697E-03	1.06104E+00	-9.14010E-02	-7.44196E-01	1.07323E-02	-6.36365E-02	1.12553E-02	2.25723E-02	-1.36937E-02	1.00000E+01
0.	0.	0.	3.31612E-01	1.43277E-01	2.79005E+00	-1.51878E-02	-7.7[illegible]E-02	1.13626E-02	
7.62233E-04	1.46568E+00	-1.31995E-01	-1.02375E+00	1.83272E-02	-7.70163E-02	1.27213E-02	2.62503E-02	-4.71270E-02	1.00000E+01
0.	0.	0.	3.56535E-01	1.64130E-01	3.13597E+00	-1.22037E-02	-1.03001E-02	1.19970E-02	
-1.63803E-04	1.95123E+00	-1.63614E-01	-2.92307E+00	1.90124E-02	-9.01251E-02	1.36045E-02	2.97133E-02	-6.33592E-02	1.00000E+01
0.	0.	0.	1.55314E-01	1.66000E-01	3.56310E+00	-9.14692E-03	-5.27334E-02	1.31370E-02	
-7.59443E-04	2.52154E+00	-2.01369E-01	-4.19753E+00	2.03673E-02	-1.02722E-01	1.49961E-02	3.37305E-02	-3.31750E-02	1.00000E+01
0.	0.	0.	8.50302E-01	2.03529E-01	4.07993E+00	-3.77631E-03	-3.37463E-02	1.55702E-02	
-1.18561E-03	3.18262E+00	-2.24131E-01	-5.61260E+00	2.37596E-02	-1.14621E-01	1.52011E-02	3.60706E-02	-1.05727E-01	1.00000E+01
0.	0.	0.	3.10372E-01	2.30361E-01	4.69233E+00	-4.25353E-04	-5.37945E-02	1.58776E-02	
-1.35022E-03	3.93988E+00	-2.37134E-01	-7.13172E+00	2.73359E-02	-1.25729E-01	1.58447E-02	4.29978E-02	-1.29053E-01	1.00000E+01
0.	0.	0.	7.67846E-01	2.61170E-01	5.40051E+00	1.73437E-03	-1.35551E-02	1.72761E-02	
-2.04935E-03	4.79658E+00	-2.33030E-01	-8.71396E+00	3.12773E-02	-1.35977E-01	1.63573E-02	4.95540E-02	-1.55362E-01	1.00000E+01
0.	0.	0.	7.14794E-01	2.71024E-01	6.20102E+00	1.47943E-03	-8.25355E-02	1.84370E-02	
-2.80393E-03	5.76044E+00	-2.26565E-01	-1.01488E+01	3.43759E-02	-1.45264E-01	1.68229E-02	5.45347E-02	-1.93524E-01	1.00000E+01
0.	0.	0.	6.54625E-01	2.33760E-01	7.06755E+00	-3.03170E-04	-3.12644E-02	1.93310E-02	
-4.08466E-03	6.63689E+00	-1.97454E-01	-1.19705E+01	3.07306E-02	-1.53472E-01	1.70459E-02	6.17554E-02	-2.13515E-01	1.00000E+01
0.	0.	0.	5.07567E-01	3.06311E-01	8.05172E+00	-4.47[illegible]E-03	-7.46655E-02	1.97580E-02	
-9.49821E-03	8.20532E+00	-1.61696E-01	-1.17608E+01	3.10297E-02	-1.57765E-01	1.66012E-02	6.34732E-02	-2.44303E-01	-1.00000E+01
0.	0.	0.	2.05312E-01	2.34427E-01	7.70952E+00	-5.03570E-02	-4.96204E-02	1.73719E-02	
-1.69731E-02	9.42559E+00	-7.68710E-02	-1.40375E+01	1.73497E-02	-1.53577E-01	1.47445E-02	7.31039E-02	-2.76238E-01	-1.00000E+01
0.	[illegible]	[illegible]	[illegible]	1.43635E-01	[illegible]	[illegible]	[illegible]		

Figure 5.2 Time History Table

1 RSRA2 RUN

VARIABLE		MEAN	STANDARD DEVIATION
RDOT	1	-.263612E-02	.57511E-01
U	2	109.4[illegible]	144.59
V	3	1.1946	12.747
W	4	-5.0312	11.967
P	5	-.13860	.45160
Q	6	.543528E-01	.10397
R	7	-.275448E-01	.77[illegible]29[illegible]-01
PHI	8	-1.6413	2.3663
THETA	9	-.54799	.69663
LONG	10	.39370	5.2497
LAT	11	0.	0.
COLL	12	.39370	5.2497
PED	13	0.	0.
XR	14	-1.4767	2.0947
YR	15	-.19944	.99325
ZR	16	2.5691	6.4153
LR	17	.351[illegible]E-01	.35202
MR	18	.783[illegible]7E-01	.12[illegible]2
NR	19	.433728E-01	.859762E-01

Figure 5.3 Means and Standard Deviations

COVARIANCE MATRIX

VARIABLE NUMBER	1	2	3	4	5	6	7	8	9	10
1	.3308E-02	.2505	.3147	-.1021	-.1453E-01	-.3767E-03	.1793E-03	-.1267E-01	-.1932E-02	.1476E-01
2		.2090E+05	449.0	-475.3	-9.832	9.325	-1.350	-318.1	-99.93	-13.43
3			162.5	-54.33	-1.501	-.3952	.6255	-12.29	-2.852	-1.059
4				143.7	-.6655E-01	-.1164	-.2866	15.04	5.434	4.512
5					.2319	-.1139E-01	.1480E-01	.2128	.4852E-01	.6723E-01
6						.1081E-01	-.4960E-02	-.1327	-.3907E-01	-.1728E-01
7							.5934E-02	-.1730E-02	.2611E-02	.1630E-01
8								5.6[illegible]	1.[illegible]21	.1230E-01
9									.4854	.1800
10										27.56

Figure 5.4 Covariance Matrix

VARIABLE NUMBER	11	12	13	14	15	16	17	18	19
1	0.	.2038E-01	0.	-.2206E-02	-.2115E-01	.3192E-01	.1772E-02	-.3591E-03	.1471E-02
2	0.	15.27	0.	-295.8	-.9225	421.4	7.791	16.50	12.13
3	0.	5.441	0.	-6.275	3.793	48.93	2.586	.1574	.3204
4	0.	4.564	0.	14.69	-2.719	-73.30	-.8960	-.6474	-.5876
5	0.	.9077E-01	0.	.1123	.3315	-.4360	.6574E-03	.3639E-02	-.2541E-02
6	0.	.2045E-01	0.	-.1324	-.4637E-01	-.7387E-01	-.7171E-02	.5369E-02	.3235E-02
7	0.	-.7755E-01	0.	.1532E-01	.5622E-01	.2496	.1316E-01	-.1427E-02	.6069E-03
8	0.	.3169	0.	4.354	-.1551	-9.951	-.3073	-.2230	-.1523
9	0.	-.5635E-03	0.	1.419	-.2392E-01	-2.736	-.3959E-01	-.7741E-01	-.4733E-01
10	0.	0.	0.	1.531	.1544	.9339	.1813E-01	-.1273	.1206E-01
11	0.	0.	0.	0.	0.	0.	0.	0.	0.
12		27.56	0.	-.2540	-.1406	-17.30	.1126	.9243E-01	.4002E-01
13			0.	0.	0.	0.	0.	0.	0.
14				4.388	.1759E-01	-6.020	-.6012E-01	-.2507	-.1437
15					.9865	1.770	.1719	.6576E-02	.1637E-02
16						70.82	.5988	.1111	.1454
17							.1239	-.1904E-03	.9833E-02
18								.1576E-01	.8076E-02
19									.7392E-02

Figure 5.4 (Continued)

CORRELATION MATRIX

VARIABLE NUMBER	1	2	3	4	5	6	7	8	9	10
1	1.000	.3012E-01	.4293	-.1402	-.5282	-.6300E-01	.3338E-01	-.9433E-01	-.4747E-01	.5544E-01
2		1.000	.2436	-.5523	-.1412	.6203	-.1212	-.9296	-.9031	-.1770E-01
3			1.000	-.3556	-.2445	-.3005	.6370	-.4075	-.3222	-.1597E-01
4				1.000	-.1153E-01	-.9343E-01	-.3104	.6360	.6567	.7174E-01
5					1.000	-.2374	.3990	.1867	.1447	.2659E-01
6						1.000	-.6193	-.5393	-.5393	-.3165E-01
7							1.000	-.9765E-02	.4665E-01	.2670E-01
8								1.000	.9225	.9899E-03
9									1.000	.4921E-01
10										1.000

Figure 5.5 Correlation Matrix

VARIABLE NUMBER	11	12	13	14	15	16	17	18	19
1	0.	.6751E-01	0.	-.1331E-01	-.3529	.4530E-01	.5293E-01	-.7467E-01	.2974
2	0.	.1406E-01	0.	-.3767	-.5424E-02	.3454	.1531	.4074	.5146
3	0.	.3130E-01	0.	-.2350	.2996	.4552	.5764	.9334E-01	.2724
4	0.	.7253E-01	0.	.3345	-.2284	-.7312	-.2120	-.4316	-.5721
5	0.	.3566E-01	0.	.1113	.7975	-.1199	.3573E-02	.6433E-01	-.6133E-01
6	0.	.3746E-01	0.	-.6263	-.4539	-.4015E-01	-.1959	.6413	.3619
7	0.	-.1913	0.	.9493E-01	.7619	.3350	.4553	-.1475	.1217
8	0.	.2553E-01	0.	.3782	-.6599E-01	-.4796	-.3638	-.7534	-.7485
9	0.	-.1241E-03	0.	.9724	-.3456E-01	-.4667	-.1614	-.8852	-.7911
10	0.	0.	0.	.1392	.2961E-01	.2114E-01	.9811E-02	-.1931	.2673E-01
11	0.	0.	0.	0.	0.	0.	0.	0.	0.
12		1.000	0.	-.2307E-01	-.2676E-01	-.3916	.6092E-01	.1252	.8656E-01
13			0.	0.	0.	0.	0.	0.	0.
14				1.000	.8452E-02	-.3415	-.8154E-01	-.9534	-.7930
15					1.000	.2142	.4916	.5219E-01	.1273
16						1.000	.1987	.1051	.2023
17							1.000	-.4303E-02	.3265
18								1.000	.7484
19									1.000

Figure 5.5 (Continued)

1 KSRA2 RUN PROBLEM- ROOT AS DEPENDENT VARIABLE *OPTIMAL SUBSET REGRESSION*

SUB-PROBLEM*****

DEPENDENT VARIABLE	1
MAXIMUM NUMBER OF STEPS	20
F-LEVEL FOR INCLUSION	2.000000
F-LEVEL FOR DELETION	2.000000
TOLERANCE LEVEL	.001000

STEP NUMBER 1
VARIABLE ENTERED 5

VARN EXPLAINED BY R-SQ .27901084
STD. ERROR OF ESTIMATION .04902625

ANALYSIS OF VARIANCE

	DF	SUM OF SQUARES	MEAN SQUARE	F-RATIO
REGRESSION	1	.11721	.11721	44.762
RESIDUAL	126	.30245	.240366E-02	

VARIABLES IN EQUATION

VARIABLE		COEFFICIENT	STD. ERROR	F TO REMOVE	
P	5	-.630801E-01	.943318E-02	44.76	(2)

CONSTANT 0.

VARIABLES NOT IN EQUATION

VARIABLE		PARTIAL CORR.	TOLERANCE	F TO ENTER	
U	2	-.528977E-01	.9301	.3207	(2)
V	3	.35450	.9402	19.16	(2)
W	4	-.11168	.9999	4.267	(2)
Q	6	-.22842	.9936	5.841	(2)
R	7	.32042	.8521	15.26	(2)
PHI	8	.432064E-02	.9651	.3027E-02	(2)
THETA	9	.356141E-01	.9790	.1599	(2)
LONG	10	.936441E-01	.9943	1.106	(2)
LAT	11	0.	1.000	0.	(2)
COLL	12	.10191	.9907	1.312	(2)
PLD	13	0.	1.000	0.	(2)
XR	14	.47957E-01	.5076	.2881	(2)
YR	15	.13342	.3641	2.265	(2)
ZR	16	-.216608E-01	.5856	.5871E-01	(2)
LR	17	.647501E-01	1.000	.5261	(2)
MR	18	-.430221E-01	.5957	.2389	(2)
NR	19	.31265	.9962	13.29	(2)

Figure 5.6 First Iteration I/O

1 MSRA2 RUN PROBLEM- RUGT AS DEPENDENT VARIABLE *OPTIMAL SUBSET REGRESSION*

STEP NUMBER 2
VARIABLE ENTERED 3

VARN EXPLAINED BY R-SQ .37445E54
STD. ERROR OF ESTIMATION .04581425

ANALYSIS OF VARIANCE

	DF	SUM OF SQUARES	MEAN SQUARE	F-RATIO
REGRESSION	2	.15756	.78782E-01	37.577
RESIDUAL	125	.26260	.21006E-02	

VARIABLES IN EQUATION

VARIABLE		COEFFICIENT	STD. ERROR	F TO REMOVE	
V	3	.1440311E-02	.325041E-03	19.16	(2)
P	5	-.5376051E-01	.870929E-02	36.10	(2)

VARIABLES NOT IN EQUATION

VARIABLE		PARTIAL CORR.	TOLERANCE	F TO ENTER	
U	2	-.11550	.9336	2.635	(2)
W	4	-.54222E-01	.9632	.3056	(2)
Q	6	-.13513	.6055	1.335	(2)
R	7	.35870E-01	.2669	.1598	(2)
PHI	8	.15656	.8229	3.535	(2)
THETA	9	.15159	.6915	3.325	(2)
LONG	10	.10550	.9972	1.366	(2)
LAT	11	0.	1.000	0.	(2)
COLL	12	.73329E-01	.5544	.6729	(2)
PEO	13	0.	1.000	0.	(2)
XR	14	.13920	.9517	2.490	(2)
YR	15	-.35112	.1040	17.44	(2)
ZR	16	-.21910	.7527	6.293	(2)
LR	17	-.25338	.6455	5.351	(2)
MR	18	-.91509E-01	.9820	1.213	(2)
NR	19	.23334	.9143	7.140	(2)

CONSTANT 0.

Figure 5.6b. Second Iteration I/O

1 RSRA2 RUN PROBLEM- NDOT AS DEPENDENT VARIABLE *OPTIMAL SUBSET REGRESSION*

STEP NUMBER 12
VARIABLE ENTERED 6

VARN EXPLAINED BY R-SQ .93210376
STD. ERROR OF ESTIMATION .01574616

ANALYSIS OF VARIANCE

	DF	SUM OF SQUARES	MEAN SQUARE	F-RATIO
REGRESSION	12	.39154	.32628E-01	131.56
RESIDUAL	115	.28521E-01	.24800E-03	

VARIABLES IN EQUATION

VARIABLE		COEFFICIENT	STD. ERROR	F TO REMOVE	
U	2	-.205564E-03	.10144E-03	4.122	(2)
V	3	.410659E-02	.4924[illegible]E-03	512.2	(2)
W	4	-.207075E-02	.25806E-03	64.39	(2)
P	5	.970075E-01	.163375E-01	35.26	(2)
Q	6	.769087E-01	.336512E-01	4.339	(2)
R	7	-1.12646	.75660E-01	224.7	(2)
THETA	9	.812311E-01	.2[illegible]E-01	12.36	(2)
CULL	12	-.542202E-02	.419547E-03	167.1	(2)
XR	14	.137427E-01	.43309E-02	10.37	(2)
YR	15	-.277997E-01	.971646E-02	8.301	(2)
LR	17	-.636146E-01	.104094E-01	37.15	(2)
NR	19	1.62159	.41751E-01	[illegible]3.6	(2)

CONSTANT 0.

VARIABLES NOT IN EQUATION

VARIABLE		PARTIAL CORR.	TOLERANCE	F TO ENTER	
PHI	6	.319961E-01	.22392E-01	.2015	(2)
LONG	10	-.396055E-02	.4971	.73711E-02	(2)
LAT	11	0.	1.000	0.	(2)
PLD	13	0.	1.000	0.	(2)
ZR	16	-.625521E-01	.72598E-01	.5462	(2)
AR	18	-.367055E-01	.12236E-01	.8635	(2)

F-LEVEL OR TOLERANCE INSUFFICIENT FOR FURTHER COMPUTATION

Figure 5.6c Last Iteration I/O

SUMMARY TABLE

STEP NUMBER	VARIABLE ENTERED	REMOVED	MULTIPLE R	RSQ	INCREASE IN RSQ	F VALUE TO ENTER OR REMOVE	NUMBER OF INDEPENDENT VARIABLES INCLUDED
1	P	5	.5282337	.27[illegible]8	.2790308	48.7643	1
2	V	3	.6122573	.3745586	.0955278	17.1612	2
3	YR	15	.6722574	.4519305	.0773719	17.4374	3
4	NR	19	.7051473	.4972327	.0453022	11.9443	4
5	XR	14	.8735375	.7630678	.2658351	130.6325	5
6	COLL	12	.8866842	.7862160	.0231482	13.1317	6
7	R	7	.9132333	.8339951	.0477791	34.5380	7
8	W	4	.9328131	.8701347	.0361396	33.1163	8
9	U	2	.9530627	.9083285	.0381938	45.1635	9
10	LR	17	.9587516	.9192046	.0108761	15.7495	10
11	THETA	9	.9641126	.9295131	.0103085	16.9643	11
12	Q	6	.9654252	.9321037	.0025906	4.1073	12

Figure 5.7 Variables Entered or Removed

LIST OF RESIDUALS

CASE NUMBER	Y X(1)	Y COMPUTED	RESIDUAL	RESIDUAL/Y	X(2)	X(3)	X(11)	X(12)	X(15)
1	-.4486E-03	-.1259E-02	.1259E-02	-.2303E+01	0.	.2159E-01	-.2823E-02	-.1952E-04	.1151E-02
2	.1237E-02	.7277E-03	.5094E-03	.4118	.6377E-02	.1009E-01	.7274E-01	.2318E-02	.1702
3	.4428E-02	.4544E-02	-.1159E-03	-.2618E-01	.1579E-01	.2435E-01	.1427	.5121E-02	.5062
4	.5942E-02	.5632E-02	.3095E-03	.5209E-01	.1928E-01	.1759E-01	.3189	.7251E-02	.4979
5	.9591E-02	.7670E-02	-.2119E-02	-.1817	.2107E-01	.2751E-02	.9271E-01	.9112E-02	.6316
6	.4744E-02	.6125E-02	-.1381E-02	-.2911	.2015E-01	-.1553E-01	.1095	.9720E-02	.7230
7	.3367E-02	.4351E-02	-.9838E-03	-.2922	.1779E-01	-.5216E-01	.1212	.1033E-01	.7562
8	.1967E-02	.2142E-02	-.1552E-03	-.7909E-01	.1375E-01	-.9140E-01	.1433	.1103E-01	.6366
9	.7622E-03	.3923E-03	.3699E-03	.4853	.1432E-01	-.1342	.1652	.1209E-01	.6565
10	-.1635E-03	-.8775E-03	.7141E-03	-4.359	.1701E-01	-.1556	.1860	.1314E-01	.6563
11	-.7595E-03	-.1699E-02	.9390E-03	-1.237	.2217E-01	-.2011	.2089	.1458E-01	.6492
12	-.1266E-02	-.2147E-02	.5613E-03	-.4103	.2377E-01	-.2241	.2304	.1590E-01	.6104
13	-.1550E-02	-.2422E-02	.8719E-03	-.5626	.2760E-01	-.2371	.2517	.1720E-01	.7674
14	-.2145E-02	-.2572E-02	.4264E-03	-.1988	.3113E-01	-.2366	.2710	.1849E-01	.7148
15	-.2664E-02	-.2673E-02	.8639E-05	-.3243E-02	.3478E-01	-.2266	.2693	.1933E-01	.6540
16	-.4085E-02	-.3260E-02	-.8247E-03	.2019	.3759E-01	-.1975	.3063	.1777E-01	.5676
17	-.9454E-02	-.9313E-02	-.1145E-03	.1209E-01	.3103E-01	-.1617	.2335	.2232E-01	.2623
18	-.1654E-01	-.1117E-01	-.5212E-02	.3423	.1765E-01	-.7607E-01	.1405	.3326E-01	-.2664
19	-.1743E-01	-.9298E-02	-.8132E-02	.4667	.1466E-01	.9639E-01	.1497	.1599E-01	-.5340
20	-.1525E-01	-.1053E-01	-.4719E-02	.3094	.1290E-01	.3260	.2234	.1477E-01	-.6686
21	-.1372E-01	-.6280E-02	-.7432E-02	.5419	.1299E-01	.6059	.2020	.1519E-01	-.8700
22	-.1216E-01	-.1476E-02	-.1068E-01	.8784	.1352E-01	.9259	.1837	.1474E-01	-.9560
23	-.1052E-01	.2062E-02	-.1258E-01	1.196	.1339E-01	1.265	.1711	.1322E-01	-1.192
24	-.9123E-02	.5038E-02	-.1416E-01	1.552	.8619E-02	1.679	.1408	.1357E-01	-1.206
25	-.7659E-02	.7370E-02	-.1527E-01	1.993	.1641E-02	2.111	.1205	.1276E-01	-1.291
26	-.6332E-02	.8909E-02	-.1524E-01	2.396	-.8860E-02	2.575	.8563E-01	.1172E-01	-1.305
27	-.3630E-02	.1450E-01	-.1873E-01	4.892	-.1408E-01	3.013	.6916E-01	.9262E-02	-1.153
28	-.1405E-02	.1065E-01	-.1206E-01	8.562	-.2139E-01	3.686	.1973	.1064E-01	-.8495
29	-.4013E-02	.7111E-02	-.1113E-01	2.769	-.4094E-01	3.954	.1712	.7993E-02	-.7773
30	-.7048E-02	.9059E-02	-.1611E-01	2.285	-.6341E-01	4.275	.8761E-01	.6592E-02	-.5352
31	-.8597E-02	.6133E-02	-.1473E-01	1.713	-.8976E-01	4.555	.6076E-01	.6594E-02	-.3077
32	-.1549E-01	.9647E-03	-.1646E-01	1.062	-.1267	4.664	-.5143E-01	.3379E-02	-.4692
33	-.2415E-01	-.1663E-01	-.6414E-02	.2655	-.1572	4.625	-.1172	-.4549E-02	-.8636
34	-.3122E-01	-.3569E-01	.4472E-02	-.1433	-.1377	4.441	-.9463E-01	-.1336E-01	-1.015
35	-.3455E-01	-.5297E-01	.1843E-01	-.5334	-.1960	4.151	-.2481E-01	-.2219E-01	-1.205
36	-.3561E-01	-.6234E-01	.2674E-01	-.7509	-.1119	3.796	-.1425E-01	-.3025E-01	-1.343
37	-.3104E-01	-.6364E-01	.3260E-01	-1.050	-.1593	3.401	.1563E-01	-.3212E-01	-1.239
38	-.2474E-01	-.5422E-01	.2948E-01	-1.192	-.1430	3.002	.2929E-01	-.2943E-01	-1.007
39	-.2137E-01	-.4724E-01	.2587E-01	-1.211	-.1232	2.569	-.2475E-01	-.2757E-01	-.9084
40	-.2154E-01	-.4135E-01	.1944E-01	-.9057	-.1178	2.116	-.1150	-.2776E-01	-.7879
41	-.2438E-01	-.4010E-01	.1571E-01	-.6444	-.9173E-01	1.658	-.1767	-.3321E-01	-.6977
42	-.2828E-01	-.4004E-01	.1175E-01	-.4157	-.9503E-01	1.218	-.2410	-.3415E-01	-.6547
43	-.3199E-01	-.4043E-01	.8436E-02	-.2637	-.9912E-01	.9152	-.2903	-.3373E-01	-.5969
44	-.3503E-01	-.4040E-01	.5404E-02	-.1544	-.1073	.4639	-.3505	-.4330E-01	-.5572
45	-.3680E-01	-.3953E-01	.2711E-02	-.7371E-01	-.1134	.1692	-.3950	-.4749E-01	-.5345
46	-.3764E-01	-.3764E-01	.4527E-05	-.1203E-03	-.1342	-.7163E-01	-.4334	-.5074E-01	-.5179
47	-.3715E-01	-.3467E-01	-.2506E-02	.7415E-01	-.1524	-.2165	-.4547	-.5307E-01	-.5059
48	-.3540E-01	-.3066E-01	-.4719E-02	.1333	-.1671	-.4250	-.4916	-.5427E-01	-.4964
49	-.3283E-01	-.2607E-01	-.6765E-02	.2060	-.1335	-.5777	-.5150	-.5433E-01	-.4897
50	-.2966E-01	-.2289E-01	-.6772E-02	.2957	-.1988	-.7330	-.5355	-.5339E-01	-.4846

Figure 5.8 Residuals

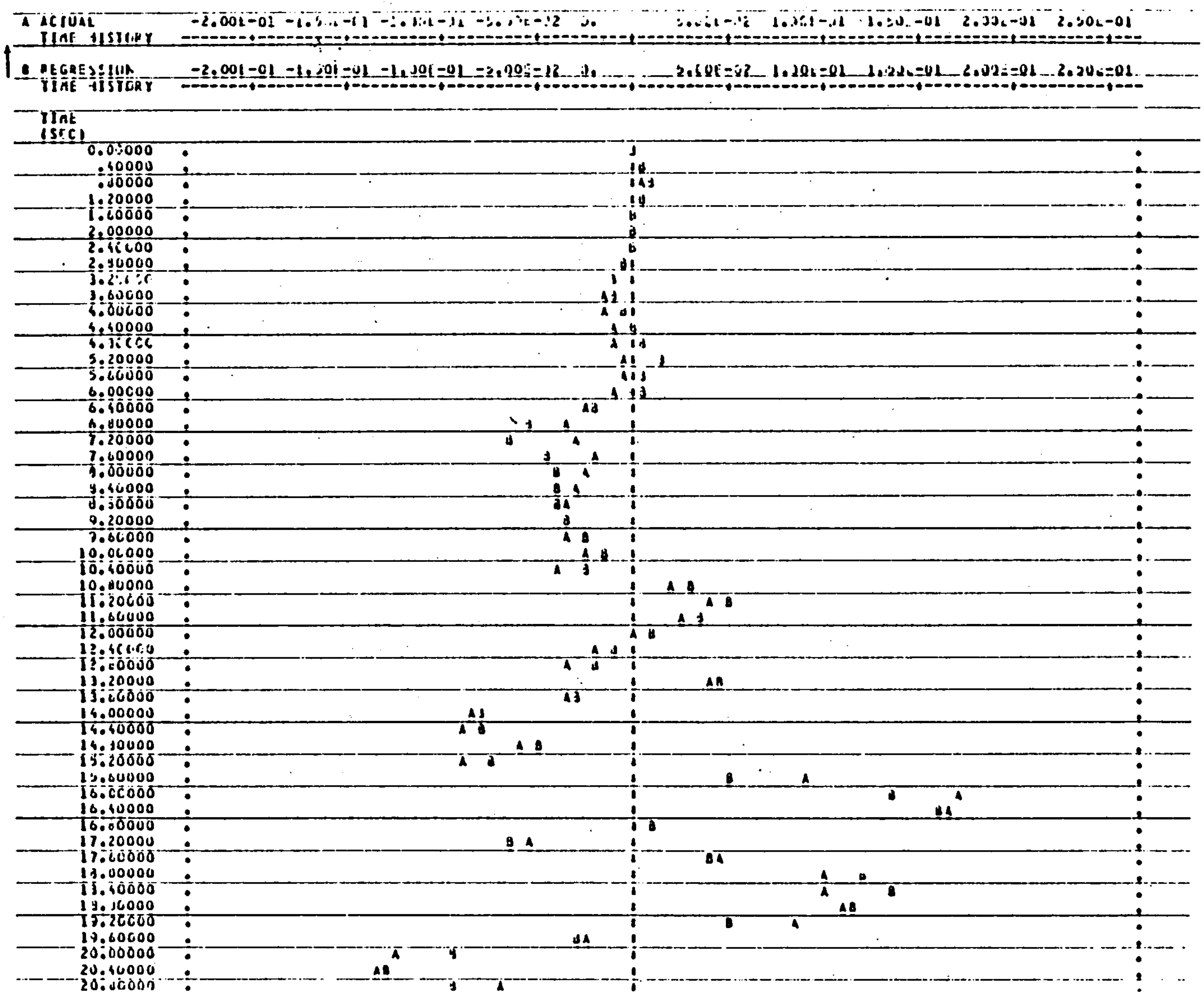

Figure 5.9 Plot of Regression Run